Agricultural Water Management 137 (2014) 104–115

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Disentangling the impacts of climate change, land use change and irrigation on the Central Rift Valley water system of Ethiopia

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ARTICLE INFO

Article history:
Received 24 November 2012
Accepted 30 November 2013
Available online 12 March 2014

Keywords:
Curve Number method
Evapotranspiration
Lake levels
River discharge
Agriculture
Intensification

ABSTRACT

The Central Rift Valley (CRV) of Ethiopia is a closed basin where claims on land and water have strongly increased over the past decade resulting in over-exploitation of the resources: a clear symptom is the declining trend in the water level of the terminal Lake Abyata. In this paper, we quantify the plausible recent impacts of climate change, land use change and irrigation water abstraction on water availability of Lake Abyata. We examined trends in lake levels, river discharges, basin rainfall, temperature and irrigation development (ca. 1975–2008), and computed the additional evapotranspiration loss resulting from temperature change and irrigated land. We also analysed land use change (1990–2007) and estimated the subsequent change in surface runoff. Temperature has increased linearly over 34 years ($p < 0.001$) whereas rainfall has not changed significantly. Consequently, increased evapotranspiration consumed 62 and 145 Mm^3 of additional water from lakes and land surface, respectively, during 1990–2007. Furthermore, an estimated 285 $Mm^3\ yr^{-1}$ of water was abstracted for irrigation in 2009 of which approximately 170 $Mm^3\ yr^{-1}$ is irrecoverable evapotranspiration loss. In addition, surface runoff has increased in the upper, and decreased in lower sub-basins of the CRV associated with extensive land use change (1990–2007). However, insight in the impact of the net increase in runoff of 260 $Mm^3\ yr^{-1}$ on the water availability for Lake Abyata remains partial because of data and methodological limitations. We conclude that the potential for agricultural intensification and its hydrological implications should be considered jointly to prevent further deteriorating Lake Abyata.

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1. Introduction

The East African Rift Valley, stretching from the Afar region in Ethiopia to Mozambique in Southern Africa, faces increasing pressure from growing populations and increasing economic development (e.g. Becht and Harper, 2002; Hengsdijk et al., 2010; Mutiga et al., 2010). The Rift Valley comprises some of the largest inland lakes of the world such as Lake Malawi and Lake Tanganyika. Many of the lakes in the East African Rift Valley have no outlet to sea, making them very sensitive to developments that affect the local hydrology and water quality (UNEP, 2004). Recent awareness of the potential impacts of climate change and major land use change on the East African Rift Valley Lakes and its population has increased concerns that current developments are unsustainable (Bezabih et al., 2011; Mango et al., 2011; Verburg et al., 2003; Zeray et al., 2007).

One of the basins in the East African Rift Valley that shows a rapid transformation is the Central Rift Valley (CRV) in Ethiopia. Claims on land and water resources have strongly increased in the CRV over the past decade due to various developments. Most obvious effect of these developments is the falling water level of Lake Abyata, which is part of the Lake Shala-Abyata National Park and forms the terminal lake of the closed CRV basin (Legesse and Ayenew, 2006). The size of this lake has been reduced by more than 50% between 1973 and 2006 (Hengsdijk et al., 2009).

The predominant livelihood strategy for the majority of the population (about 2 million) in the CRV is the small mixed rain fed farming system comprising cereals (wheat, barley, maize and teff) and livestock. As a consequence of a growing population the cropping area more than doubled at the expense of forests and grassland between 1973 and 2006 (Garedew et al., 2009). Land use change may affect the local hydrology through its impact on

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http://dx.doi.org/10.1016/j.agwat.2014.02.014
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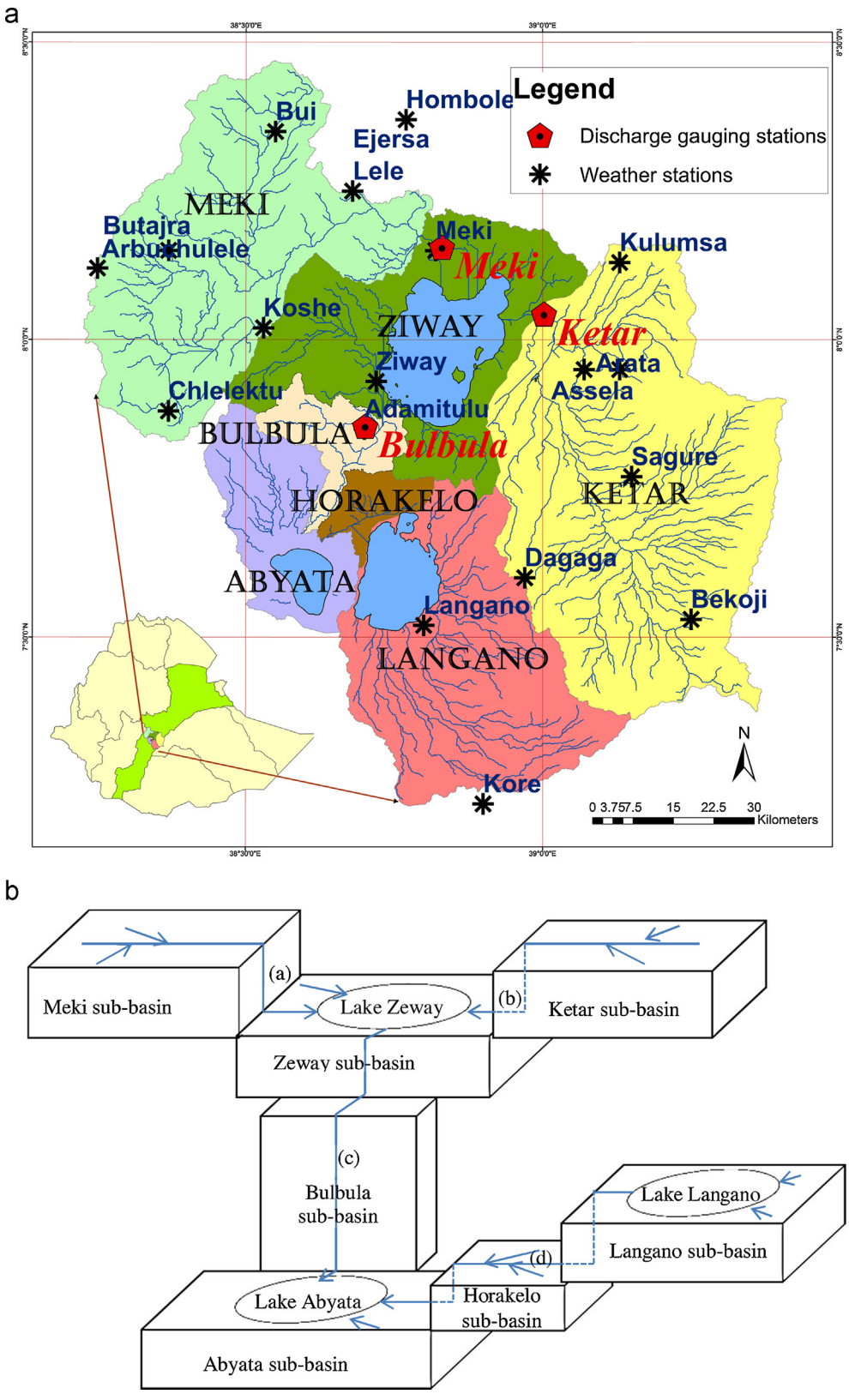

Fig. 1. (a) Map of the Central Rift Valley which consists of seven sub-basins (shown in different colours), i.e. Meki, Ketar, Zeway, Bulbula, Horakelo, Abyata and Langano. Further, 17 weather stations (*) are shown, as well as three discharge gauging stations (♦) used in the study. (b) Schematic representation of the seven sub-basins in the Central Rift Valley and their inter-connectivity. Letters (a), (b), (c) and (d) represent the Meki, Ketar, Bulbula and Horakelo Rivers, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

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